Table 1. MRI Definiation: maximum grades of MRI-detected marginal (4 tibiofemoral locations) osteophytes for knees Kellgren-Lawrence (KL) 0-2

WORMS osteophytes (maximum grades in either central medial/lateral femur/tibia)	KL Grade on X ray		
	0 (N=26) n	1 (N=9) n	2 (N=16) n
0	22 (85%)	1 (11%)	0 (0%)
1	3 (12%)	5 (56%)	2 (13%)
2	1 (4%)	2 (22%)	6 (38%)

4 marginal TF locations using the WORMS scoring system (scale 0-7). All knees KL0-2 were included in the analysis. In our sample, the minimum marginal OP size detected on MRI in KL2 knees was a MRI WORMS grade 1, defined as a tiny or equivocal OP (Table 1). Since radiographically-detectable OPs in KL2 knees are by definition 'definite' OPs, accordingly we defined the MRI grade 1 OP to be the minimum 'definite' OP on MRI. The diagnostic performance of this MRI grade was assessed, using X-ray as the reference. We further evaluated an alternative MRI grading in which 'definite' OPs were defined as a WORMS grade 2. In addition, risk of ROA according to MRI OP grade was assessed using exact logistic model and using the definite MRI OP grade (1) as the reference.

Results: Eighty knees from 40 subjects were imaged. The mean age of subjects was 57 (SD±11) years, 30 (75%) were women, 35 (88%) were white and 31 (78%) had a body mass index ≥25. 26 knees were graded KL0, 9 knees KL1 and 16 KL 2. Of the knees graded as KL2, 2 had a maximum OP size of 1, 3 knees a maximum OP grade 2, 2 knees a maximum OP grade 3 and 9 knees a maximum OP grade ≥4. A grade 1 MRI OP, defined as a "definite" OP, had a sensitivity of 100%, a specificity of 74.3% and an accuracy of 82.3% in diagnosing ROA. Numbers were comparable using a grade 2 OP as a "definite" OP (Table 2).

Table 2. Agreement and diagnostic performance for the presence of radiographic OA (= KL2) of marginal definite MRI osteophytes based on the results of "definite" osteophytes from Table 1

Feature	No. of findings on X ray				Sensitivity (%)	Specificity (%)	Accuracy (%)
	TP	TN	FP	FN			
Maximum WORMS grade 1	16	26	9	0	100	74	82
Maximum WORMS grade 2	14	26	11	0	100	70	78

Abbreviations: TP = true positive; TN = true negative; FP = false positive; FN = false negative.

Risk of ROA increased with increasing OP size albeit not statistically significant due to small sample size (Table 3).

Table 3. Presence of marginal MRI osteophytes and risk of radiographic OA*

MRI Osteophyties (maximum WORMS score inc 4 marginal localtions)	KL Grade		Odds Ratio	p-value
	0 or 1 (N=35) n	2 (N=16) n		
0	23 (68%)	0 (0%)	0.2**	0.17
1	8 (24%)	2 (13%)	1 (reference)	n/a
2	3 (9%)	6 (38%)	7.0	0.11
≥3	1 (3%)	8 (50%)	24.4	0.009

*Knees with a maximum grade 1 of a marginal osteophyte in any of the 4 marginal tibiofemoral locations is defined as "definite" and the reference group.
**Indicated a median unbiased estimate.

Conclusions: A grade 1 MRI OP in any of the 4 TF marginal locations is highly sensitive in diagnosing ROA and shows good specificity. Small (grade 1) MRI-detected OPs show a good diagnostic performance in the detection of ROA and may be defined as "definite" OPs. Further validation in larger studies is needed.

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MEDIAL LATERAL RATIO OF KNEE CONDYLES BONE MINERAL DENSITY IN WOMEN WITH OSTEOARTHRITIC KNEE

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Purpose: We aimed to quantify a subchondral bone sclerosis of the femoral and tibial condyles, and developed medial lateral ratio of bone mineral density (BMD) in patients with varus knee osteoarthritis (OA) using dual energy x-ray absorptiometry (DXA) (CORR 1997). Medial lateral ratio of the knee condyles might have the possibility of monitoring in the progression of varus knee OA. The purpose of this study was to assess the relationship between medial lateral ratio of the knee condyles and various factors.

Methods: This study involved 171 consecutive women with varus knee OA at our institution. The patients were considered to have knee OA if they had Kellgren-Lawrence grades of 2 or higher. In addition, the patients with knee OA showed knee pain during walking, climbing stair and/or descending stair. All patients underwent knee radiograph and DXA at the lumbar spine, proximal femur and knee condyles. Medial and lateral condyle BMDs at the femur and the tibia were measured, and medial lateral ratio of the femoral and tibial condyles were calculated. Anteroposterior and lateral knee radiographs were taken while the patients were in the standing position. The femorotibial (FT) angle was defined as the lateral angle between the femoral and tibial shaft axes, and the femoral condylar-tibial plateau (FCTP) angle was defined as the angle between the tangents to the femoral condyles and the tibial plateau marginal line. Body mass index (BMI) was calculated as an index of obesity. SPSS for Windows was used for statistical analysis. Data were expressed as means ± standard deviations and were assessed using Pearson's correlation coefficient. Significance was set at $p < 0.05$.

Results: The mean age, BMI, FT angle and FCTP angle in women with varus knee OA were 69.6±8.8 years, 25.5±4.2 kg/m^2, 182.6±5.9° and 5.8±3.6°, respectively. The mean medial and lateral condyle BMDs at the femur were 1.195±0.295 and 0.689±0.153 g/cm^2, respectively. Also, the mean medial and lateral condyle BMDs at the tibia were 0.953±0.241 and 0.634±0.142 g/cm^2, respectively. The mean medial lateral ratio at the femur and tibia were 1.79±0.58 and 1.53±0.46, respectively. There were significant association between medial lateral ratio at the femur and medial lateral ratio at the tibia ($r = 0.758$, $p < 0.001$). Medial lateral ratio of the femoral and tibial condyles were significantly correlated with greater FT angle ($r = 0.488$, $p < 0.001$ and $r = 0.547$, $p < 0.001$, respectively). Also, medial lateral ratio of the femoral and tibial condyles were significantly correlated with greater FCTP angle ($r = 0.499$, $p < 0.001$ and $r = 0.591$, $p < 0.001$, respectively).

Conclusions: Medial lateral ratio of the femoral and tibial condyles increased significantly with the progression of varus deformity and joint space narrowing. Medial lateral ratio of the femoral and tibial condyles has the possibility of monitoring in the progression in women with varus knee OA.

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TECHNIQUE FOR DETERMINING OPTIMAL LYON-SCHUSS X-RAY BEAM ANGLE

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Purpose: Development of disease modifying osteoarthritis drugs (DMOAD) need to demonstrate preservation of the joint space width (JSW) which is commonly measured by X-ray. The Lyon-schuss (LS) method of positioning the knee and aligning the X-ray beam so the anterior and posterior tibial margins are aligned on the projection image has been shown to be the most sensitive method for measuring joint space narrowing (JSN). The disadvantage of the LS method is that the optimal beam angle requires the use of fluoroscopy or multiple x-rays and iterating until alignment is obtained. We present a technique for objectively determining the correct LS angle form the first x-ray, allowing a reduction in time and X-ray exposure to the subject.

Methods: This retrospective study used MRI and X-ray from the A9001140 longitudinal knee OA study, to develop and test this method. In this study, the Kellgren and Lawrence (KL)=0 subjects had a body mass index (bmi) < 28 and the OA subjects, KL=2 and 3, had a bmi > 30.From the MRI a 3D reconstruction of the medial tibial plateau was done for 30 female subjects and the plateau width and depth was measured. The ratio of the depth/width was found to be 1.78 (±0.14) and was consistent for KL scores of 0, 2 and 3. The width of the medial tibial plateau was measured on the X-ray and using this ratio the depth of the tibial plateau was estimated. The MRI were only used to establish this ratio and were not required for application of this technique. Using this information, and measuring the inter margin distance (IMD) the correct LS angle was determined using the following method.

Acquire the first X-ray at a known angle, measure IMD, measure medial plateau width, calculate depth = 1.78*width, calculate IMD angle as sin α = IMD/depth. The correct LS angle is the sum of α and the existing X-ray angle. However, because it is impossible to tell from the X-ray if the posterior or anterior tibial rim is higher there is uncertainty whether to increase or decrease the beam by α. As a result there is a 50% chance of moving in the wrong direction and requiring a third X-ray.
To test this technique the baseline x-rays of 70 subjects from the A9001140 study were used. Each subject had a fixed flexion (FF) x-ray acquired at 10° and a successful LS x-ray, defined as an IMD $<$ 1.5mm acquired through iteration. The optimizing technique was applied using the FF x-ray as the starting point and the result compared to the "optimal" beam angle used to acquire the LS x-ray.
Results: The observed LS angles ranged from 1 to 17 degrees with a median value of 9. The predicted LS angles ranged from 3 to 16 degrees with a median value of 9. The angles predicted by this method were within 1 degree of the LS angle determined by iterative x-ray acquisitions in 83% of the cases. For 7% of the cases the predicted angle was between and 1 and 2 degrees of the observed LS angle. For KL scores of 0, 2, and 3 the predicted LS angle was within 2 degrees of the observed angle 97%, 83%, and 84%, respectively. In cases where there was a difference between the prediction and the acquired LS x-ray it was not possible, in this retrospective study, to determine if the predicted beam angle would have also yielded an acceptable LS x-ray. Additional studies are required to verify the appropriate ratio for different subject populations such as male subjects.
Conclusions: Using this technique the optimal LS x-ray angle could be objectively determined permitting a successful acquisition with 2 or 3 X-rays reducing the overall radiation exposure over previous methods which often required 4 or more x-rays or fluoroscopy. This also permits the x-ray technologists to reliably acquire a LS x-ray with a more systematic approach that doesn't require intuition or experience.

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RISK FACTORS FOR PREVALENT TIBIO-FEMORAL CARTILAGE DAMAGE IN SUBJECTS WITH FREQUENT KNEE PAIN: THE JOG STUDY

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Purpose: Cartilage damage is one of the hallmark features of osteoarthritis and may be assessed indirectly by radiography or directly by MRI. Cross-sectionally, cartilage damage is associated with subchondral bone marrow lesions (BMLs), bone attrition, meniscal damage, malalignment and ligament pathology. Certain demographic factors in addition seem to increase the risk of cartilage damage in the knee joint. Purpose was to analyze the cross-sectional associations of several demographic and MRI-based risk factors with prevalent cartilage damage semiquantitatively assessed at 3 T MRI.
Methods: The JOG study includes 177 subjects aged 35-65 with chronic, frequent knee pain. 3 T MRI of both knees was performed at baseline on a Siemens Trio system using the same pulse sequence protocol as in the Osteoarthritis Initiative (OAI): sagittal IW 2D TSE FS, sagittal 3D DESS WE, axial MPR of SAG 3D DESS WE, coronal MPR of SAG 3D DESS WE. MRIs were assessed by one expert MSK radiologist according to the WORMS scoring system. Cartilage status was scored on a scale from 0-6 using all 5 sequences in each of 5 subregions (i.e., anterior, central and posterior subregions in the tibia and central and posterior subregions in the femur) in both the medial and lateral compartments for a total of 10 subregions. Meniscal status, meniscal extrusion, and the presence of synovitis/effusion was included in the analysis. All MR features were divided into two categories: present (score $\geq$1) and absent (score=0). We performed a subregion-based analysis using GEE to account for the clustering of subregions within a knee and knees within an individual. Multivariate models were adjusted for age, gender and BMI. All MRI risk factors were adjusted for each other in the multi-adjusted model.
Results: 51.2% of participants were men, mean BMI was 29.1 ($\pm$ 4.1). Baseline Kellgren/Lawrence grades were (worst K/L grade for either left or right knee): K/L 0: 37 (20.9%) knees, K/L 1: 14 (7.9%) knees, K/L 2: 26 (14.7%) knees, K/L 3: 81 (45.8%) knees K/L 4: 19 (10.7%). Of the 353 knees, 304 knees (88.6%) and 1,153 subregions (28.0%) exhibited cartilage damage. Of the subregions showing cartilage damage focal damage (WORMS 2.0 or 2.5) was observed in 243 subregions (21.0%). BMLs were present in 12.3% of subregions. Comparing subregions with vs without BMLs, 82.8% vs 15.5% exhibited cartilage damage, respectively.
Significant predictors of the presence of cartilage damage in this cross-sectional analysis were age, presence of synovitis or effusion, prevalent meniscal damage, meniscal extrusion and BMLs (Table 1).

Table 1. Cross-sectional associations of demographic and MRI-based risk factors with prevalent cartilage damage

Risk factor	Reference	Odds Ratio[4] (95% confidence intervals)
Age -mid tertile[1]	Youngest tertile	1.88 (1.27-2.79)*
Age -oldest tertile[1]	Youngest tertile	2.60 (1.73-3.92)*
Gender - female[1]	Male	0.92 (0.68-1.26)
BMI – overweight (25-30)[1]	BMI < 25	1.36 (0.87-2.15)
BMI – obese (> 30)[1]	BMI < 25	1.48 (0.95-2.30)
Synovitis and effusion[1]	All synovitis /effusion scores = 0	1.83 (1.28-2.63)*
Meniscal damage[2]	No meniscal damage (WORMS=0)	3.63 (2.50-5.25)*
Meniscal extrusion[2]	No meniscal extrusion	1.71 (1.24-2.37)*
BML[3]	No BML in subregion	16.59 (11.66-23.60)*

[1]cartilage damage in any of 12 subregions
[2]cartilage damage in same compartment as meniscal damage or extrusion (6 subregions medial or lateral)
[3]cartilage damage in same subregion as BML
[4]multi-adjusted GEE model accounting for correlations within and between knees
* statistically significant at p ≤ 0.05

Conclusions: Confirming previous work several MRI detected tissue pathologies are strongly associated with cartilage damage in adjacent subregions. The strongest cross-sectional predictors of cartilage damage were subchondral BMLs followed by meniscal pathology. Of the demographic factors only age showed an association with cartilage damage. The course of events leading to chondral pathology needs to be determined in longitudinal studies with multiple time-points.

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36 MONTH FOLLOW-UP OF 3T MRI KNEE CARTILAGE T2 MEASUREMENTS IN INDIVIDUALS FROM THE OAI INCIDENCE AND CONTROL COHORT

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Purpose: To compare knee cartilage T2 relaxation time values in individuals from the Osteoarthritis Initiative incidence cohort with risk factors for knee osteoarthritis versus normal controls at baseline and after 36 months
Methods: Forty-nine individuals (19 male, 30 female) with risk factors for knee osteoarthritis were randomly selected from the incidence cohort. Inclusion criteria were 45-55 years of age, BMI of 19-27 kg/m^2, no knee pain in either knee (WOMAC score of zero) and a *Kellgren-Lawrence (KL)-Score* equal or greater than one in right knee radiographs at baseline. In addition, using the same age, BMI and WOMAC criteria, 51 individuals (17 male, 34 female) from the control cohort with no risk factors for knee osteoarthritis and a *KL-Score of zero in right knee radiographs* at baseline were included. Baseline and 36 month follow-up 3T MR images of the right knee were obtained. Cartilage segmentation and T2 relaxation time measurements were performed in five compartments (patella, medial/lateral femur and tibia). General linear models were used to adjust for age, gender and BMI and to compare means and changes of T2 values of the two groups.
Results: The incidence group showed higher mean T2 values in all compartments at baseline and after 36 months. Differences reached significance in the medial femur compartment at baseline and 36 month follow-up ($p<0.001$, respectively $p=0.031$). The mean T2 value in the medial femur compartment amounted 52.43ms in the incidence group (versus 49.88ms in the control group) at baseline and 55.37ms (versus 53.61ms) after 36 months. T2 values of all compartments increased over 36 months in both groups (p-values $<$ 0.001). The increases of the T2 values were comparable between the incidence and control group in all compartments and differences were non significant ($p>0.05$). The highest increases were found in the medial tibia compartment (7.48ms in the incidence group versus 7.78ms in the control group) and medial femur compartment (2.85ms versus 3.73ms)